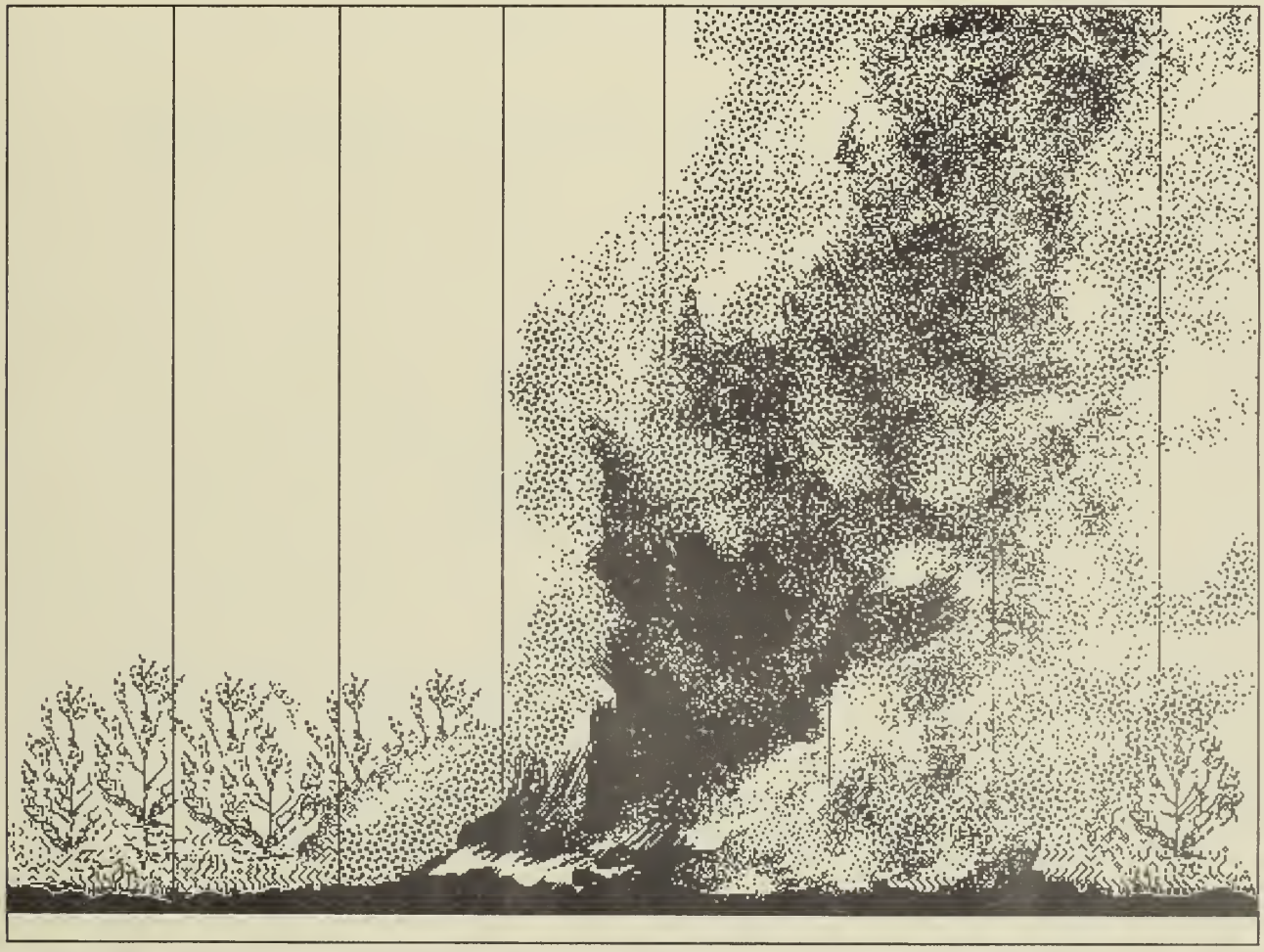
Technical Note 382

SASEM

Simple Approach Smoke Estimation Model



U.S. Department of the Interior **U. S. Bureau of Land Management**

SASEM

Simple Approach Smoke Estimation Model

By

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Table of Contents

ABOUT THIS NOTE

This Technical Note presents a simple, easy-to-use, computer model of smoke dispersion from controlled burns. This paper contains background on why such a computer program has been developed by the Bureau of Land Management (BLM), the theoretical basis for the model, a guide on how to run the model and suggestions for its use in practical prescribed burning applications.

ABOUT SASEM

Background. The BLM is engaged in prescribed burning to improve range quality, clear logging debris and reduce the hazard of wildfires on the lands it manages. In recent years, both state and federal regulatory authorities have become interested in the contribution to the total suspended particulate matter (TSP) and consequent visibility reduction from controlled burning by land management agencies.

In particular, during 1985 the BLM applied to the Wyoming Department of Environmental Quality, Air Quality Division (WDEQ/AQD) for permission to conduct several prescribed burns. After re-examination of state air quality regulations the Administrator of the AQD requested that the BLM (and other practitioners of prescribed fire in the state) present evidence that burning activities would not violate ambient air quality standards for particulates. This request was based on two sections of the state air quality regulations. First, Section 13 of the Wyoming regulations defines each fire as a permitable entity. Second, Section 12 of the Wyoming air quality regulations prohibits the AQD Administrator from permitting any activity that would violate the Wyoming Ambient Air Quality Standards for total suspended particulates.

When this requirement was handed down, no analysis tool was available from or approved by the AQD for use in securing permission to burn. No emission factors, fuel consumption factors or plume rise calculations had been defined for Wyoming range burns. Also, onsite weather data were seldom available. Consultation with Wyoming DEQ/AQD personnel resulted in the decision that the best means of fulfilling the requirement was a simple screening level model. Computer modeling was chosen because:

1) it would provide a reproducible analysis technique suitable for regulatory review

2) the 1977 amendments to the Clean Air Act mandated use of modeling for prevention of significant deterioration (PSD) analyses and since then modeling has been used routinely in all areas of air quality permitting.

The screening model proposed would be easily applied and remain within the limitations set by the lack of knowledge about the emission regimes of Wyoming rangeland fires. The BLM became the agency responsible for developing the model since it was the first to desire to perform controlled burns after the requirement was made. Through cooperative efforts with scientists of the U.S. Forest Service, the Wyoming AQD, and the BLM, the Simple Approach Smoke Estimation Model (SASEM) was developed.

Purpose. The Simple Approach Smoke Estimation Model was designed to be a screening tool for analyzing air quality impacts of controlled burns on federal lands. To understand both the limitations and the strengths of SASEM, one must first understand the implications of the four key phrases in this statement:

1) Screening Tool – The purpose of a screening analyses is to make a first cut at a regulatory decision, i. e. whether a new emission source should be given a permit. Such a procedure also should be simple to perform, require minimal expertise and have limited data requirements. A quick, relatively clear yes/no decision is the desired result. An ambiguous result indicates that a more sophisticated approach is required to resolve the question. A screening analysis in this context is then technically correct, but simplifying assumptions made tends to produce conservative results. The model would more likely over- than under-predict particulate concentration. When this method is used and the screening procedure indicates no regulations will be violated by the new source, the built-in bias toward over-prediction will ensure that no violations occur with the actual source, even though the test was made with a very simple procedure.

2) Air Quality Inputs – The air quality impacts which SASEM was designed to analyze are total suspended particulate concentration and reduction in visual range due to smoke from controlled burns. The most important criteria for significance of air quality impacts are the local and national air quality standards. Though they have been proposed, there are as yet no standards for visibility impact. The model thus provides as results:

   a) the maximum concentration and distance from the fire at which particulates would occur.

   b) an indicator of whether an ambient concentration standard would be exceeded in the vicinity of the fire and over what range of distances from the fire this level of impact could be expected.

   c) two estimates of the minimum visual range which would be expected from the situation modeled.

3) Controlled Burns–SASEM was needed to integrate the process of determining fuel consumption, emission production and concentration calculation for controlled burns. The greatest need for SASEM was in the area of emission, not concentration calculations. General purpose air quality models already existed which could be applied to controlled burning. Developing a model specialized for controlled burn analyses allowed us to make the model easy for agency personnel to use. Those expected to use the model have a general technical background and knowledge of fire management, but no special training in meteorology or air quality. With SASEM the fuel consumption and particulate emission factors were to be calculated from simple fuel type and fuel loading (weight/area) information and expected fire line intensity (heat production/length fire line). The information required by the model was

chosen from among the parameters collected or evaluated by fire managers in the process of developing a fire prescription. Specifying controlled burns places a limit on the size of fire for which emission and related information must be obtained. SASEM was not intended to predict impacts due to large wildfires.

4) Federal Lands–Two features specific to managing federal lands were considered in the design of SASEM. First, as mentioned before, the land managers responsible for use of prescribed fire do not necessarily have specific training in meteorology or air quality. The model was made very easy to use, requesting required information in terms and measuring units already familiar to fire managers. Second, the concept of a 'plant boundary,' beyond which air quality impacts must not exceed the standards, is ambiguous in this case. Neither the limited area around the fire where work is done, nor the boundary of the agency ownership would be reasonable choices. Plant boundaries are often significantly farther from the source than the area where a fire crew works. Since a prescribed burn could be anywhere from adjacent to or many miles from the boundary of federal ownership, use of this boundary would lead to varying regulatory stringency for each fire. Furthermore, in multiple use areas, among the resources which land management agencies must protect are recreational suitability and general esthetics, both of which air quality or visibility degradation might impact. For the state of Wyoming, the compromise reached was to consider the plant boundary to be an arbitrary distance of 1-kilometer from the fire. SASEM was adjusted so no impacts are reported at less than this 1-kilometer boundary.

THEORY

Design. The SASEM program calculates particulate emission rate, ambient TSP concentration and minimum visual range due to smoke from controlled burning. The design of SASEM was kept simple by building it out of well known components rather than creating an entirely new modeling approach. The procedure was implemented on a small computer as an interactive program with necessary information requested in the language of the fire management officers most likely to use it. The program itself was developed using ideas from two previous screening techniques:

1) the *Southern Forestry Smoke Management Guidebook* (USDA, 1976)

2) two Models of Historical Significance from the EPA UNAMAP model series, PTMAX and PTDIS (Turner and Bussee, 1973).

SASEM produces tables of maximum ground-level concentration of particulates, the distance at which this concentration would occur and the range of distances from the fire over which specified ambient standards would be exceeded, if any. Tables are also produced of minimum visual range at

The general form of SASEM follows the guidebook example of having an integrated process of determining air quality impacts. This includes calculation of fuel consumption, particulate emission

factor, plume rise, ambient concentration and visual range all within a single framework. Though the actual computations were not generally used, the measurement units and language for requesting information used in SASEM are predominantly those of the guidebook.

Like the PTMAX model, SASEM calculates the maximum ambient concentration and its distance from the fire through a variety of wind speed and stability conditions preselected within the model. Alternatively, a range of conditions (the fire prescription) which the fire officer determines to meet the objectives of the prescribed burn and to maintain safety, can be applied. Since this model was intended for regulatory purposes, these maximum concentrations are then compared to the National Ambient Air Quality Standard for total suspended particulates and any applicable local standard (in our case the Wyoming ambient particulate standard). If a standard is exceeded, the model determines the range of distances from the fire in which this occurs.

As in the PTDIS model, concentrations at specified distances are calculated. In the SASEM program specific locations were intended primarily as sensitive receptor sites, such as highways and towns, where visibility could be important because of humans perceiving smoke as a nuisance. Two techniques were used to calculate a simple scattering coefficient at these locations. The scattering coefficient was then used to calculate the minimum visual range produced by the specified smoke plume.

Fuel Consumption. Within the program, SASEM calculates a particulate emission rate and height to which the smoke plume rises. To do this, the rate at which fuel is consumed must be calculated. As a screening level model, fairly simple assumptions are made about fire behavior in order to calculate fuel consumption. Neither small scale nor large scale fire geometry are considered within SASEM. The burned area is always assumed to be square, with a fire line the length of a side of that area, moving across it evenly during the entire burn period. The fire duration is, however, intended to include the major part of the smoldering period of the fire as well as the period of advance of the flaming front. Fuel moisture and fuel element size are known to affect fuel consumption, however, these are considered only indirectly in the basic model as a factor indicating the proportion of the total fuel available which is actually burned. This factor is set by the fuel type. A more elaborate model of fuel consumption and emission production (Sandberg and Peterson,1984) which does include some of these factors can be used by SASEM, but currently only for broadcast logging slash fuels.

This simple fire behavior description and the general lack of information about rates of consumption of range fuel types resulted in the use of straightforward coefficients based on broad fuel categories as the means of assessing fuel consumption in SASEM. The rate of fuel consumption by the fire is then

$$F = CF \cdot FL \cdot A / T \qquad (1)$$

where

F = The fuel consumption rate (mass fuel consumed per unit time)

CF = The fuel consumption factor (proportion of available fuel which is consumed in the fire)
FL = The fuel loading (mass fuel per unit area)
A = The area of the site to be burned
T = The total duration of the fire

The proportion burned for fuel types currently accepted by the model are given in Table1. These values are contained in the program and are automatically selected by choosing a particular fuel type.

Table 1. Emission Characteristics Related to Fuel Type

Fuel Type	Heat Produced (Mcal/kg)	Proportion Burned (percent)	Residence Time (seconds)
Sagebrush	3.50	70	480
Wood	3.88	50	960
Grass	3.33	90	120

Emissions. Unlike most simple models, the particulate emission rate is calculated within the SASEM program. The emission rate is determined from the fuel consumption rate and the ratio of fuel consumed to particulates emitted

$$Q = F \cdot EP \qquad (2)$$

where

Q = The emission rate (mass particulates emitted per unit time per unit length for fire lines)
EP = The particulate emission factor (mass particulates emitted per mass fuel burned)
F = The fuel consumption rate (mass fuel consumed per unit time)

The emission factor is calculated according to a technique determined by Ward, et al. (1980) using fire line intensity.

$$EP = 0.0195 - 7.37 \cdot 10^{-5} \cdot I + 1.45 \cdot 10^{-7} \cdot I^2 \qquad (3)$$
for $I < 470$ kW/m

$$EP = 0.0167 + 2.43 \cdot 10^{-7} \cdot I \qquad (4)$$
for $470 \text{ kW/m} <= I < 1750 \text{ kW/m}$

where

I = The fire line intensity (heat production per length per time for the flaming front, units of kW/m for the coefficients given)

These emission factors were derived from experiments in which understory vegetation of palmetto-gallberry stands was burned in Florida. Though not the closest in resemblance to Wyoming sageland in appearance of vegetation types, it is the only shrub type for which particulate emission observations were available.

Estimates of fire line intensity, fuel loading, fire area and fire duration of prescribed burns are readily available before the event since the fire managers are required to obtain them as they prepare a burn prescription.

Plume Rise. Plumes are considered nonbuoyant in nearly all air quality models which include line sources. These models were designed primarily for analyzing the impact of such sources as vehicle exhaust along highways. No plume rise is required for such emissions. The only widely available model which includes buoyant line sources is BLP (Scire and Schulman, 1980). BLP is a complex model developed for assessing the impact of aluminum reduction plants. The line sources for this model are about 100 meters long, whereas fire lines start at 100 meters and range up to a kilometer in length. It was decided for plume rise treating the fire line as a series of point sources would produce just as reasonable results, with far simpler computations. Plume rise is calculated from the heat output of the fire using the standard point source equations (Briggs, 1969).

$$H = 0.0101 \cdot QH^{3/4} / U \quad (5)$$
for stability A to D and $QH < 1.4 \cdot 10^6$ cal/s

$$H = 0.0847 \cdot QH^{3/5} / U \quad (6)$$
for stability A to D and $QH > 1.4 \cdot 10^6$ cal/s

$$H = 0.917 \cdot QH^{1/3} \cdot U^{1/3} \quad (7)$$
for stability E and F

where stability is in Pasquill-Gifford (P-G) categories and

H = The maximum height of the smoke plume (units of meters for the. coefficients given)

QH = The heat release rate for a section of the fire which contributes to plume rise (units of cal/s for the coefficients given)

U = The average wind speed during the burn (units of m/s for the coefficients given)

The use of dispersion day for stability is a special case of requesting information in terms known to the fire managers. For practitioners of prescribed burning in the state of Wyoming, the National Weather Service provides an index of smoke dispersion ranging from excellent to poor in four levels based on temperature lapse rate and wind speed. P-G stability categories correspond to the dispersion day index roughly as given in Table 2.

Table 2. Comparison of Dispersion Day Index and Pasquill-Gifford Stability Category

Dispersion Day	Stability Category
Excellent	A, B
Good	C
Fair	D
Poor	E, F

In SASEM the dispersion day category is requested and the corresponding P-G stability category substituted by the model. For the categories excellent and poor, stabilities B and E were chosen out of the two possibilities for each, somewhat arbitrarily.

When considering a fire line, it is apparent that all the heat produced by the fire usually does not go into producing a single coherent plume. As a simple first approximation, the average depth of the fire line was chosen as the characteristic dimension which determines what proportion of the heat of the fire acts to raise the plume along any part of its length. Because of reinforcement effects along the line, the appropriate length is probably greater than that which we have chosen, but no approximation of this effect is readily available. The depth of the fire line is calculated from the time it takes the fire to pass by a particular point and the fire rate of spread as:

$$D = FR \cdot RT \qquad (8)$$

where

D = The depth of the fire line
FR = The rate of spread of the fire
RT = The residence time of the fire

Residence time, the time it takes the fire to pass a particular point, depends on the size of the largest fuel elements which will burn. Anderson (1969) gives an empirical relation for the residence time in minutes as eight times the diameter in inches of these fuel elements. The resulting residence times for the fuel types currently accepted by the model, are given in Table 1. The fire rate of spread, for the purposes of this model is simply the length of a side of the burn area divided by the duration of the burn. The length of the fire line is then divided by the fire depth determined above to obtain a number of 'plumes' by which the line can be represented. The total heat output is then divided by

the number of plumes to produce the heat output used for plume rise calculations. In the case of burning slash piles, the heat output of a single, average slash pile is calculated and used to determine the plume rise for all slash piles according to the Briggs equations.

The average heat output of the fire is calculated from the heat content of the fuel and the amount of fuel burned. Different fuels have different heat content, mostly because of moisture and mineral content variations. Based on the fuel types, the heat content values used by the model are given in Table 1. Taken with the adjustment for fire line plume development given above, the heat output used to calculate plume rise is:

$$QH = HC \cdot F / NP \qquad (9)$$

where

F = The fuel consumption rate (mass fuel per unit area)
HC = The heat content of the fuel (heat produced per mass fuel burned)
NP = The number of effective plumes which the fire line represents; always equals 1 for slash piles
QH = The heat release rate for a section of the fire which contributes to plume rise (units of cal/s for the coefficients given)

Ground Level Concentration. The plume dispersion is calculated using the standard (Turner, 1970) Gaussian concentration equations. The modification for infinite line sources perpendicular to the wind is used for fire lines. The line is nearly perpendicular to the wind direction in most cases, since fire line movement is controlled by the wind. At large distances from a fire, the assumption of an infinite line is not correct, so the point source equation is used. For slash piles, the point source equation is used and it is assumed that all the piles are close enough together that multiplying the concentration produced from one pile by the number of piles, as though all were located at the same point, will give an accurate enough concentration estimate. This technique is more likely to give a larger maximum concentration than spreading the piles out in their actual geometric configuration and is much simpler to compute.

Not all the smoke remains with the rising plume (USDA, 1976). Some becomes unentrained from the plume at lower levels, moving with the wind flow and dispersing at that level. The suggested ratio is 60 percent rises to 40 percent does not rise. The heat release rate and atmospheric stability can both push this ratio either lower or higher. However, for lack of appropriate observations, a fixed ratio is used in SASEM. Since smoke is observed to become unentrained from the plume at all levels from the surface to just below final rise height, the level of the unentrained smoke used in the model is one-half the final plume rise.

Since prescribed burns are relatively short in duration, the particulate standards under consideration are 24-hour average conditions. If a fire is less than 24 hours in duration, then a receptor would be affected only for that duration and the 24-hour average should be adjusted accordingly. Also, wind and stability conditions do not remain constant for very long periods of time. Therefore, a factor was included in the model to account for the fact that the same wind speed, wind direction and stability conditions are unlikely to persist for more than eight hours. The time and persistence factor is thus

$$ADJ = T / 86400 \quad \text{for } T < 21600 \text{ s} \tag{10}$$

$$ADJ = (T + 172800) / 777600 \quad \text{for } 21600 \text{ s} <= T <= 86400 \text{ s} \tag{11}$$

$$ADJ = 0.333333 \quad \text{for } T > 86400 \text{ s} \tag{12}$$

where

ADJ = The time and persistence adjustment factor with time in seconds

The final ground level concentration is thus

$$C = (0.6 \cdot C1 + 0.4 \cdot C2) \cdot ADJ \tag{13}$$

$$C1 = \frac{2Q}{\sqrt{2\pi} \cdot \sigma_z \cdot U} \cdot \exp\left[-\frac{1}{2} \left\{ \frac{H}{2\sigma} \right\}^2 \right] \tag{14}$$

$$C2 = \frac{Q}{\sqrt{2\pi} \cdot \sigma_z \cdot U} \exp\left[-\frac{1}{2} \left\{ \frac{H}{2\sigma_z} \right\}^2 \right] \tag{15}$$

for fire lines at distances downwind < 50 times the fire line length

$$C1 = \frac{Q}{(\pi \cdot \sigma_y \cdot \sigma_z \cdot U)} \exp\left[-\frac{1}{2} \left\{ \frac{H}{\sigma_z} \right\}^2 \right] \tag{16}$$

$$C2 = \frac{Q}{(\pi \cdot \sigma_y \cdot \sigma_z \cdot U)} \cdot \exp\left[-\frac{1}{2} \left\{ \frac{H}{2\sigma_z} \right\}^2 \right] \tag{17}$$

for slash piles or fire lines at a distance 50 times the fire line length

$$\sigma_y = a \cdot x^b \tag{18}$$

$$\sigma_z = c \cdot x^d \tag{19}$$

where

C = The average 24-hour ground level concentration
C1 = The ground level concentration from the plume at full height
C2 = The ground level concentration from the plume at half the full height (unentrained smoke)
x = The downwind distance
σ_z = The width of standard deviation of concentration in the vertical
σ_y = The width of standard deviation of concentration in the horizontal
a, b, c, d = The appropriate empirical coefficients
H = The maximum height of the smoke plume (units of meters for the coefficients given)

The values of a, b, c and d used are those from the EPA CDM model (Busse and Zimmerman, 1973), among others. Initially, concentrations are calculated at the point of maximum concentration. The distance of this point from the fire can be determined from the line and point source equations. From analysis of these equations, the maximum surface concentration occurs where:

For fire lines

$$X_{max} = \left(\frac{H}{C}\right)^{1/d} \qquad (20)$$

$$X_{max} = \left[\frac{H}{(\sqrt{2} \cdot c)}\right]^{1/d} \qquad (21)$$

For slash piles

where

X_{max} = The distance to the maximum surface concentration

The maximum concentration is calculated and compared to the applicable standards. If the standards are exceeded, then the program increments outward at 100 meter intervals in both directions to 10 kilometers to determine the range of distances from the fire in which this occurs. If concentrations still exceed the standards at 10 kilometers, further tests are made at 1 kilometer intervals out to 100-kilometers. Since the Gaussian plume equation is not valid beyond 100 kilometers, this is the maximum distance from the fire that the program will report an superfluity of the standards. For each of the meteorological conditions chosen, the maximum concentration, its point of occurrence and either 'No Violation' or the distance range for which the primary and/or secondary standard are exceeded are reported.

Visibility. Smoke can cause highway safety problems and be the source of general nuisance calls in populated areas. For these reasons, the Wyoming AQD asked that the model also include some assessment of visual range reduction. Also, many states are considering adding visibility controls to their air quality regulations.

Visual range is the distance at which contrast between a solid black object and a solid white background is reduced to 2%. If there is a known uniform concentration of particulates surrounding the observer, the visual range is (Koshmieder, 1924)

$$VR = 3.9 / s \quad (22)$$

$$s = sr + sc \cdot C \quad (23)$$

where

VR = The visual range
s = The scattering coefficient (proportion of light scattered per path length)
sr = The Rayleigh scattering coefficient of air (0.00001 m^{-1})
sc = The backscatter to concentration ratio

In this model, particulate concentrations from two different calculation techniques are used to estimate the scattering coefficient. First, the concentration, at the distance of the receptor, based on the same plume dispersion equations as the test for regulatory excess, is used. For this case, the backscatter to concentration ratio used is 5.0 m^2/g based upon recent observations of power plant plumes in the southwestern U.S. (Molenor and Malm, 1988).

For the second case, a simpler concentration calculation (Packham and Vines, 1978) is used which was developed for estimating visual range reduction from controlled burns in Australia. This calculation more nearly approximates the uniform concentration surrounding the observer assumed by the Koshmieder relation and is independent of stability conditions. With this technique, concentration is calculated by determining the total mass of particulates produced from the fire, divided by the total volume of air which passes the area of the fire within a specified mixing depth over the duration of the burn. This would result in a uniform concentration with distance downwind of the fire. To account for dispersion, the value is adjusted as inversely proportional to the increase in width of a 12.5-degree sector spreading out from the fire site to the receptor site. The concentration is then:

$$C = FL \cdot A \cdot EP \cdot DF / (L \cdot U \cdot MH \cdot T) \quad (24)$$

$$DF = D0 / (D0 + x) \quad (25)$$

$$D0 = L / [2 \text{ Tan } (12.5°/2)] \quad (26)$$

where

DF = The dispersion adjustment factor
L = The length of the fire line
MH = The mixing height
D0 = The distance from the fire line at which a 12.5-degree sector converges

This concentration is an average for the entire burn period. To determine the minimum visual range during the burn, the maximum concentration is desired. To approximate the period of maximum emission, the average concentration is multiplied by a factor of three. From their studies, Packham and Vines also determined a backscatter to concentration ratio for the particulates generated by the fires they observed as 2.0 m^2/g. The difference between the two ratios is probably due to the nature of the particles involved. The plumes from the Molenor and Malm study were from distant sources in the southwestern U.S. The particles observed undoubtedly had traveled long enough to grow due to the addition of hygroscopic water attachment. Packham and Vines measurements were of brushfire smoke particles which had travelled for only a few hours at most and were less likely to have any attached water. In the model, each ratio is used with the corresponding concentration estimate for determining the backscatter for calculating visual range.

USER'S GUIDE

The Simple Approach Smoke Estimation Model is available in both source code and executable code form for a variety of computers. This technical note includes a diskette with source and executable code suitable for use on IBM PC compatible computers. For information on obtaining the model in a form suitable for use on other computers (minis, mainframes, Apple Macintosh, etc.) contact the authors at:

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The program was written in ANSI Standard FORTRAN-77. Thus, a listing of the program which can be entered into any computer with a FORTRAN-77 compiler is available.

One of the advantages of SASEM is that its simplicity allows the information required by the model to be largely self-explanatory. Thus, for most fire managers it is possible to just plunge in, start the model and answer the questions.

Using the SASEM program involves several steps which may be repeated as many times as needed:

1) Start the program

2) Request help if necessary

3) Enter the required fire description information

4) Enter the required meteorological information

5) Enter the required sensitive receptor information

6) Make corrections to the information entered, if necessary

7) Indicate the types of reports desired and whether to display and/or print them

8) Calculate the results

9) Terminate the model and print the results, if necessary.

Steps 3 through 8 can be repeated for any number of fires before the program is ended. If several fires are modeled in one run, it is not necessary to answer every question every time. One can skip to the correction step immediately, keeping the values from the previous fire and changing only those for which new values are desired.

Help is available any time values are being entered simply by answering the question with a question mark (?). If help is requested at the beginning of the program, however, there are two options available. One can obtain descriptions of any individual variable immediately, or a printout can be requested, listing the descriptions of all variables. If the help printout is requested the program then ends so the user can determine which of the required information is already available and which must be obtained elsewhere. Appendix A is a listing of the help printout.

To ease entering values when the answer to a question is unknown or uncertain, default values are provided for all variables. A default is selected by pressing <RETURN> (on some computers this key is labeled <NEWLINE> or <ENTER>) instead of entering a value in answer to a question. The defaults for each question are available from the help for that question if they are not specifically listed in the question itself.

For the PC compatible version of the model provided with this report, the model is started by simply placing the diskette in the first drive and typing A:SASEM. Shortly thereafter the SASEM logo should be displayed on the computer screen. This display will last for about 15 to 20 seconds, then the main menu will be presented. At that time three options are available as indicated below the main menu:

1) Type ? for a description of the information required by the model

2) Type Q to exit the program without doing anything

3) Press the <RETURN> key to continue on to the section of the program where the required information is requested.

As previously indicated, when help is requested at this point in the program, requests for information about individual variables can be made interactively, or a printout of all information on all the variables can be requested, after which the program halts.

The quit option will terminate the program immediately with no input requests or computations being made. The command which will allow the user to cancel the program at any time is also displayed below the help, quit or continue choices also. This may be useful when the user continues on to entering values requested by the program. While SASEM provides a means of changing values improperly entered, there may be some cases where knowing how to just quit and start from scratch would make this option the easiest way to set up an orderly run.

Selecting continue enters the input section of the program where the fire description, meteorology and visibility sensitive receptor information is requested. During this step, entering a question mark instead of a value in answer to a question will result in additional information about the request being displayed. Pressing the <RETURN> key immediately instead of entering a value indicates that the default value for that variable is to be used. The actual value used as a default is displayed before the program proceeds to make the next request.

After all questions have been answered, a list of the values specified for each is presented and the user is given the opportunity to change any which may have inadvertently been entered incorrectly.

Once the information has been entered to the user's satisfaction, the type of results desired are requested. The values entered into the program and the emission calculations are always entered in the printout so they are available if any questions arise at a later date. If desired, these two reports plus the model results may be displayed on the computer terminal.

An example of the results from a typical SASEM run are given in Appendix B. This printout consists of the following sections:

1) The information provided in answer to the model questions

2) The visibility sensitive receptor descriptions, if any

3) Emission related factors calculated or provided by the model

4) A table which lists for each meteorological condition combination possible, the
   a) Dispersion day index
   b) Wind speed in miles per hour
   c) Maximum concentration of TSP in micrograms per cubic meter
   d) Distance from the fire to the point of maximum TSP concentration
   e) For the primary and secondary standards either NO VIOLATION or the distance range in miles from the fire over which the concentration is greater than the standard
   f) The height of the maximum rise of the smoke plume in meters

5) A table which lists for each sensitive receptor for each meteorological condition combination possible if sensitive receptors were specified, the
   a) Receptor name
   b) Distance the receptor is from the fire
   c) Direction the fire is seen from the receptor
   d) Dispersion day category
   e) Wind speed in miles per hour
   f) Wind direction on a 16 point compass
   g) Visual range calculated using the Packham and Vines (1978) 12.5 degree sector averaged concentration and scattering to concentration ratio
   h) Visual range calculated using the Gaussian plume concentration and the Molenor and Malm (1988) scattering to concentration ratio.

The echo of the information entered in response to the questions presented by the program and the emission related parameters will always be part of the printout. If sensitive receptors are being analyzed, their descriptions will also appear in the printout. The results of the analysis are printed only if desired. This is so a series of alternatives can be tried with the results being displayed on the screen but not printed. Then runs with fire description and prescription alternatives which result in favorable smoke abatement can be printed. The value of this potential in the model is demonstrated in the application sections of this note.

APPLICATIONS

Two applications of the model are demonstrated in this note. First, the results of SASEM are compared to several alternative techniques for estimating the smoke impacts from controlled burns. This test demonstrates that the results of SASEM are comparable to existing techniques while using the model is considerably easier. Second, situations are shown in which an analysis of model results will allow a fire prescription to be modified so the air quality impact of the burn is reduced.

Model Comparison. In the past, smoke management analyses have been done either through a series of typical scenarios given in the *Southern Forestry Smoke Management Guidebook* or by adapting general-purpose air quality models. Since observations are not currently available against which to test SASEM, results from our model will be compared to a typical scenario from the guidebook and two general air quality models which include line sources, PAL (Petersen, 1978) and BLP.

The guidebook leads one through a series of decision steps and hand calculator computations to determine emission rates. Then, the concentrations for a series of scenarios corresponding to the fuels and emission rates chosen are presented. One of these scenarios is expected to be close enough to the proposed situation to provide useful information.

PAL is a moderately complex model for simulating point, area and line sources. To use this model for smoke management, the emission rates and plume rise must be computed separately since neither is determined in the program for line or area sources. This information is then entered into the model and results obtained.

BLP is a special model for complex buoyant point and line sources used by developers of aluminum reduction plants. Since it is the only readily available model (as part of the EPA UNAMAP series) which includes plume rise for line sources, it may be the most applicable to smoke management for prescribed burns of the previously developed models. However, as with other models, the emission rates must still be calculated before using the computer program. Also, by default, the BLP model includes a power-law wind profile and gradual plume rise calculations. Since these are not used by SASEM, PAL or the guidebook, BLP was run both having this default setup and having its options set so it used the same final plume rise, height and constant wind profile as the other models.

To compare the three models (SASEM, PAL and BLP) with the Southern Forestry Smoke Management Guidebook on an equal basis, a guidebook scenario was chosen and the description given for it was entered into each model. The scenario chosen was for palmetto-gallberry fuels with a backing fire, C stability class, wind speed 8 m/s, mixing height of 1500 m, 800 m fire line, emission rate of 0.168 g/m/s and a total heat release rate of 37.682 Mcal/s. All techniques were performed in such a way that a 24 hour average concentration was produced since this is the type of result which SASEM produces automatically for comparison to the 24 hour ambient standard.

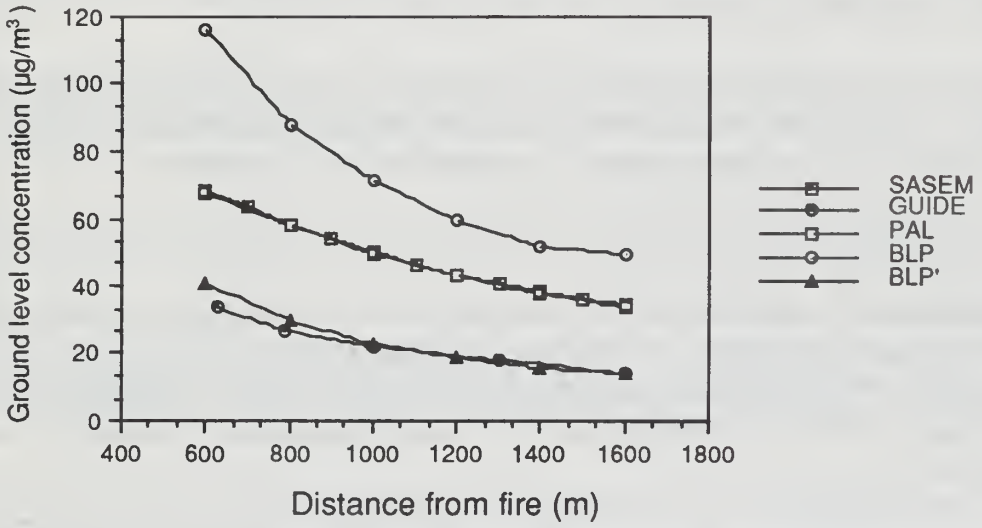
The results from the guidebook and applying the scenario to each model are summarized in Figure 1. These graphs of concentration versus distance from the center of the fire line allow SASEM, the guidebook, PAL and BLP with and without the power-law wind profile and gradual plume rise to be compared for the fire line described above.

Since all the techniques are fundamentally based on the Gaussian plume equations, the maximum concentration for all of them occurs at the same point very near the fire. For regulatory purposes in Wyoming, however, the concentration is only required to meet the standards at a distances of 1 kilometer and greater from the fire.

The guidebook gives the concentration at 1-km distance as 110 $\mu g/m^3$. The guidebook, however, includes no averaging period in its calculations, while SASEM assumes the results will be compared to the 24-hour standard. Thus, the figures in the graph are adjusted for the 4.8-hour duration of the fire by multiplying them by 4.8/24. The 24-hour average concentration is thus 22 $\mu g/m^3$.

The inputs to SASEM corresponding to this scenario are a good dispersion day, 17.9 mi/hr wind speed, 1500-meter mixing height, 158-acre fire, 2750 lb/acre fuel loading and 180 Btu/ft/s fire line intensity which burns for 4.8 hours. For this situation, SASEM produced a maximum concentration at 1.0 km of 49.9 $\mu g/m^3$.

Figure 1. Comparison of SASEM Results and Those of Similar Air Quality Models.



For PAL the same meteorology and fire dimensions were used. From this information, the emission rates and plume heights were calculated and entered into the model. For the full rise plume, the emission rate was 0.101 g/m/s and the plume rise was 33.0 m. For the unentrained smoke, the emission rate was 0.067 g/m/s and plume height was 16.5 meters. The 24-hour average was obtained by running the model for 24 hours, the first 4.8 of which were at the full emission rate, but no emissions during the remainder of the day. At the kilometer distance from the center of two 800 meter line sources, PAL produced a ground level concentration of 49.2 $\mu g/m^3$. At 1-kilometer down wind from an end of the line source, the resulting ground level concentration was 24.6 $\mu g/m^3$.

The same scenario was used with the BLP model. This model requires that the heat output of the entire line source be entered in terms of the buoyancy flux. For our situation the buoyancy flux for the fire line was 1386 m^4/s^3. The emission rate and fire line description were the same as for PAL. The-24-hour average concentration was also obtained in the same way as with PAL. As previously indicated, the default for this model is to use gradual plume rise and a power-law wind profile. For this setup, the BLP model produced a concentration of 71.3 $\mu g/m^3$ at a distance of 1.0 kilometer from the center of the fire line. If additional input information is supplied to remove the power-law wind profile and to use only the final plume rise, then the concentration is reduced to 23.0 $\mu g/m^3$.

The main reason for the lower concentrations produced by the southern fuels guidebook is the higher plume rise it uses. For the guidebook calculations the heat, of the entire fire line is used in the plume rise determination.

When the concentrations at 1 kilometer from the center of the fire line for PAL and SASEM are compared, the results appear almost identical. The difference between this result and the example given for PAL with the concentration measured directly downwind from one end of the fire line show the effect of including plume/receptor geometry in the model.

The results of BLP tend to indicate that though the model equations include factors to account for entrainment of ambient air into a line plume, the dominant effect is still the point source plume rise equation. The primary indication of this is the similarity of the guidebook results to the BLP results with only final plume rise and constant wind profile. Both techniques also use the entire heat of the fire to raise the plume. This is not realistic for a near kilometer fire line.

Overall, the results of SASEM are comfortably within the range of the variation obtained from current models. In particular, for this scenario, SASEM produced results nearly identical to PAL, a model in the EPA UNAMAP series which is considered to be conservative.

Smoke Management. Smoke management is not just knowing when dispersion of smoke from a fire can cause air quality problems. It is also knowing about and being able to make changes in the fire prescription which can reduce such problems when they might be expected to occur. The following example is intended to demonstrate how SASEM can be used to accomplish this type of smoke management.

A fire is to be used to reduce the slash cover in site preparation for replanting after clearcutting. The unit to be burned is 16 acres. The total fuel loading is 37 tons per acre. Because of the thin and rocky soil, the fire line intensity is to be kept below 700 Btu/ft/sec so the nutrient and water content of the soil is disturbed as little as possible before the replanting. By lighting the fire using hand carried drip torches making several small widely separated lines, the fire line intensity can be kept to a nominal 400 Btu/ft/sec to allow a margin of error. This would result in a fire duration including the major part of the smoldering period of 8 hours. Unfortunately, as can be seen in Table 3, this would also severely limit the meteorological conditions under which the burn could take place without smoke impacts which exceed the primary and secondary ambient particulate standards (Wyoming enforces the secondary standard).

Table 3. SASEM Results for Smoke Management Scenario #1

Disp Day	Wind Speed (MPH)	Distance to Maximum Concentration (Microg/m-cube)	Exceedences of Standards: Primary* Maximum Concentration (Mi)	Secondary* Distance Downwind From (Mi)	To (Mi)	Plume From (Mi)	To (Mi)	Rise (m)
EXC	2.0	269.8	1.50	1.25	2.06	.69	4.11	412.
EXC	3.0	269.7	1.06	.87	1.43	.56	2.80	275.
EXC	4.0	269.8	.81	.68	.99	.56	2.17	206.
EXC	5.0	269.4	.68	.56	.81	.56	1.80	165.
EXC	6.0	269.8	.56	.56	.68	.56	1.49	137.
EXC	7.0	265.6	.56	.56	.62	.56	1.30	118.
EXC	8.0	256.4	.56	NO VIOLATION		56	1.18	103.
EXC	9.0	244.8	.56	NO VIOLATION		.56	1.06	92.
EXC	10.0	232.4	.56	NO VIOLATION		.56	.93	82.
GOOD	5.0	269.8	1.25	1.00	1.80	.56	4.17	165.
GOOD	6.0	269.7	1.04	.79	1.48	.61	3.40	137.
GOOD	7.0	269.8	.87	.68	1.12	.56	2.86	118.
GOOD	8.0	269.8	.75	.62	.93	.56	2.49	103.
GOOD	9.0	269.5	.68	.56	.81	.56	2.17	92.
GOOD	10.0	269.5	.56	.56	.75	.56	1.93	82.
FAIR	7.0	269.8	2.70	1.96	4.07	.78	7.49	118.
FAIR	8.0	269.8	2.26	1.64	3.19	.64	7.48	103.
FAIR	9.0	269.8	1.92	1.73	2.66	.61	7.51	92.
FAIR	10.0	269.8	1.62	1.44	2.31	.57	7.46	82.
POOR	2.0	1181.0	4.59	.62	7.51	.62	11.24	94.
POOR	3.0	687.8	6.08	.86	7.51	.62	7.51	108.
POOR	4.0	468.7	7.43	1.46	7.43	.90	7.43	119.
POOR	5.0	62.7	8.67	NO VIOLATION		NO VIOLATION		128.
POOR	6.0	43.8	9.84	NO VIOLATION		NO VIOLATION		136.
POOR	7.0	32.4	10.95	NO VIOLATION		NO VIOLATION		143.
POOR	8.0	24.9	12.01	NO VIOLATION		NO VIOLATION		149.
POOR	9.0	19.8	13.04	NO VIOLATION		NO VIOLATION		155.
POOR	10.0	16.1	14.02	NO VIOLATION		NO VIOLATION		161.

* *THE PRIMARY PARTICULATE STANDARD IS 260. MICROGRAMS PER CUBIC METER*
THE SECONDARY PARTICULATE STANDARD IS 150. MICROGRAMS PER CUBIC METER

The wind speed under which burning could take place on excellent dispersion days in states which only enforced the primary standard is probably too high for safety considerations. Under poor dispersion conditions, no standards would be violated; however, such conditions generally occur only at night during the burning season of most areas. Also, the main reason the concentrations are less for these conditions is that the poor dispersion results in the plume taking longer to reach the ground and thus more horizontal dispersion has taken place. If the dispersion conditions should change while the plume is still present, much greater ground level concentrations could occur. It is therefore unlikely that any air quality control agency would accept merely restricting burning to the conditions for which the model indicates there would be no violations.

Checking back over the model results indicates that most of the violations occur over very short distance ranges close to the fire. Under these circumstances, increasing the fire intensity would likely produce a greater decrease in ground level particulate concentration due to increased plume height than the increase in particulates produced by the hotter, faster moving fire. Increasing the fire line intensity to the maximum allowed for the site preparation (700 Btu/ft/s), and consequently reducing the fire duration to about 4 hours, actually results in no violations for a wide range of meteorological conditions as shown in Table 4. This leaves no margin for error in the prescription. Some areas would probably receive more heat than is desirable. Resource management often results in compromises between competing needs such as these between minimizing impacts to soil nutrients and air quality.

Table 4. SASEM Results for Smoke Management Scenario #2

			Exceedences of Standards				
		Distance to	Primary*	Secondary*			
Disp	Wind	Maximum	Maximum	Distance Downwind			Plume
Day	Speed	Concentration	Concentration	From	To	From	To	Rise
	(MPH)	(Microg/m-cube)	(Mi)	(Mi)	(Mi)	(Mi)	(Mi)	(m)
EXC	2.0	149.3	3.26	NO VIOLATION		NO VIOLATION		971.
EXC	3.0	149.3	2.26	NO VIOLATION		NO VIOLATION		647.
EXC	4.0	149.3	1.75	NO VIOLATION		NO VIOLATION		485.
EXC	5.0	138.5	1.95	NO VIOLATION		NO VIOLATION		388.
EXC	6.0	138.5	1.66	NO VIOLATION		NO VIOLATION		324.
EXC	7.0	138.5	1.44	NO VIOLATION		NO VIOLATION		277.
EXC	8.0	138.5	1.28	NO VIOLATION		NO VIOLATION		243.
EXC	9.0	139.2	.62	NO VIOLATION		NO VIOLATION		216.
EXC	10.0	144.6	.62	NO VIOLATION		NO VIOLATION		194.
GOOD	5.0	149.3	3.16	NO VIOLATION		NO VIOLATION		388.
GOOD	6.0	149.3	2.59	NO VIOLATION		NO VIOLATION		324.
GOOD	7.0	149.3	2.19	NO VIOLATION		NO VIOLATION		277.
GOOD	8.0	149.3	1.89	NO VIOLATION		NO VIOLATION		243.
GOOD	9.0	149.3	1.66	NO VIOLATION		NO VIOLATION		216.
GOOD	10.0	138.9	2.16	NO VIOLATION		NO VIOLATION		194.
FAIR	7.0	14.3	12.35	NO VIOLATION		NO VIOLATION		277.
FAIR	8.0	17.8	9.75	NO VIOLATION		NO VIOLATION		243.
FAIR	9.0	21.5	7.91	NO VIOLATION		NO VIOLATION		216.
FAIR	10.0	149.3	6.57	NO VIOLATION		NO VIOLATION		194.
POOR	2.0	130.0	12.01	NO VIOLATION		NO VIOLATION		149.
POOR	3.0	58.6	15.91	NO VIOLATION		NO VIOLATION		171.
POOR	4.0	33.3	19.43	NO VIOLATION		NO VIOLATION		188.
POOR	5.0	21.5	22.68	NO VIOLATION		NO VIOLATION		203.
POOR	6.0	15.0	25.74	NO VIOLATION		NO VIOLATION		215.
POOR	7.0	11.1	28.65	NO VIOLATION		NO VIOLATION		227.
POOR	8.0	8.5	31.43	NO VIOLATION		NO VIOLATION		237.
POOR	9.0	6.8	34.10	NO VIOLATION		NO VIOLATION		246.
POOR	10.0	5.5	36.69	NO VIOLATION		NO VIOLATION		255.

* *THE PRIMARY PARTICULATE STANDARD IS 260. MICROGRAMS PER CUBIC METER*
THE SECONDARY PARTICULATE STANDARD IS 150. MICROGRAMS PER CUBIC METER

Another alternative would be simply not to burn as much in one day. With an area as small as that proposed in this scenario, that might not be practical. If eight acres are burned on two days using the firing pattern originally described for the area so the fire line intensity is kept to 400 Btu/ft/s and the fire duration on each day is only four hours, the resulting ground level concentrations are given in Table 5. Now, the fire can proceed at 6 to 8 miles per hour under excellent dispersion conditions. For these smaller burns it appears only a small increase in fire line intensity would be required to provide a wide range of burning conditions. If the time is available, this would force less of a compromise between the requirements for a good planting site preparation burn and the limitations imposed by air quality considerations.

Under other conditions, different smoke management techniques might be applied. For instance, the fuel loading could be reduced. This can be done by chipping the slash on part of the area, rather than burning. It can also be accomplished by allowing firewood gathering on the area before burning. Another alternative is to pile some of the slash instead of leaving it all broadcast. Slash piles generally burn much hotter and quicker. The point source dispersion equation used for piled material includes more influence of lateral dispersion than the infinite line source equation used for broadcast fuels.

At this time SASEM does not include the effects of varying fuel moisture on fuel consumption. Since high fuel moisture can greatly reduce the amount of fuel consumed (and thus the potential for particulates to be produced), including a provision for burning only under high fuel moisture may convince the regulatory agency to allow a burn with marginal violations according to the model to proceed.

Table 5. SASEM Results for Smoke Management Scenario #3

Disp Day	Wind Speed (MPH)	Distance to Maximum Concentration (Microg/m-cube)	Exceedences of Standards Primary* Maximum Concentration (Mi)	Secondary* Distance Downwind From (Mi)	To (Mi)	From (Mi)	To (Mi)	Plume Rise (m)
EXC	2.0	157.7	2.24	NO VIOLATION		1.74	2.86	640
EXC	3.0	157.7	1.56	NO VIOLATION		1.25	1.99	427.
EXC	4.0	146.3	1.64	NO VIOLATION		NO VIOLATION		320.
EXC	5.0	146.3	1.34	NO VIOLATION		NO VIOLATION		256.
EXC	6.0	147.7	.62	NO VIOLATION		NO VIOLATION		213.
EXC	7.0	157.5	.75	NO VIOLATION		.62	.93	183.
EXC	8.0	157.6	.62	NO VIOLATION		.56	.81	160.
EXC	9.0	157.6	.56	NO VIOLATION		.56	.75	142.
EXC	10.0	157.1	.56	NO VIOLATION		.56	.62	128.
GOOD	5.0	157.7	2.00	NO VIOLATION		1.51	2.69	256.
GOOD	6.0	157.7	1.64	NO VIOLATION		1.27	2.20	213.
GOOD	7.0	157.7	1.38	NO VIOLATION		1.07	1.88	183.
GOOD	8.0	157.7	1.20	NO VIOLATION		.95	1.63	160.
GOOD	9.0	147.0	1.54	NO VIOLATION		NO VIOLATION		142.
GOOD	10.0	147.1	1.37	NO VIOLATION		NO VIOLATION		128.
FAIR	7.0	30.0	.62	NO VIOLATION		NO VIOLATION		183.
FAIR	8.0	157.7	4.54	NO VIOLATION		2.86	5.54	160.
FAIR	9.0	157.7	3.66	NO VIOLATION		2.42	5.59	142.
FAIR	10.0	157.7	3.14	NO VIOLATION		2.09	5.13	128.
POOR	2.0	843.3	5.53	.87	5.53	.62	6.03	119.
POOR	4.0	39.1	.62	NO VIOLATION		NO VIOLATION		149.
POOR	5.0	24.2	.62	NO VIOLATION		NO VIOLATION		161.
POOR	6.0	16.5	.62	NO VIOLATION		NO VIOLATION		171.
POOR	7.0	11.9	.62	NO VIOLATION		NO VIOLATION		180.
POOR	8.0	9.0	.62	NO VIOLATION		NO VIOLATION		188.
POOR	9.0	7.1	.62	NO VIOLATION		NO VIOLATION		196.
POOR	10.0	5.7	.62	NO VIOLATION		NO VIOLATION		203.

* *THE PRIMARY PARTICULATE STANDARD IS 260. MICROGRAMS PER CUBIC METER*
THE SECONDARY PARTICULATE STANDARD IS 150. MICROGRAMS PER CUBIC METER

SUMMARY

The Simple Approach Smoke Estimation Model was designed to provide a tool for the analysis of smoke dispersion from prescribed burns. In particular, it was intended to serve as a screening level model which provides a conservative estimate of the possibility that a given burn will cause an exceedence of air quality standards or be a public nuisance due to visibility impairment of public highways or residential areas. By comparison with currently available dispersion models which include line sources, SASEM appears to fulfill this purpose. Furthermore, because of the extremely simple data requirements, all of which are already being collected for purposes of making fire prescriptions and are requested in terms familiar to fire management personnel, the tool is readily accessible to those who can make the best use of it. This note has also demonstrated how, through the application of SASEM, smoke management can become a practical part of prescribed burning rather than merely an ideal discussed in the abstract.

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Appendix A

Listing of the SASEM Help File

1. Fire/site descriptive name (20 characters maximum)
   This is to label the printout so results can be easily located later.

   Default is Fire NN where NN starts at 1 and
   increments for each fire in the modeling session.

2. Date of the burn (any format)
   This is to label the printout so results can be easily found later.

   Default is date left blank

3. Fuel arrangement (PILED slash, BROADcast)
   PILED is generally for logging slash pushed into piles or windrowed.
   BROADcast is any fuel type spread over the area.

   Default arrangement is BROADcast

4. Type of fuel to be burned (SAGEbrush, GRASS, WOOD)
   Primary fuel type only. SAGEbrush or GRASS most likely
   in range areas, WOOD most likely in forest areas.

   Default is SAGE for BROADcast or WOOD for PILED

5. Size of burn (acres)
   Include only one burn, if multiple burns are to be made on separate days
   or on widely separated areas, do not lump them,
   do one at a time.

   Default is 100 acres. for broadcast or
   10 piles of 100 sq ft each.

6. Fuel loading (lb/acre)
   Give the average fuel loading for the entire burn area,
   as carefully as it can be estimated in pounds per acre.
   or for slash piles in lb/slash pile (average).

   Default for broadcast is 5500 lb/A, for piled slash 8000 lb/pile

7. Fire line intensity (Btu/ft/sec)
   This will be produced by the BEHAV Model in the process of making a fire prescription.

   Default for broadcast is 145 Btu/ft/sec
   for piled slash is 1450 Btu/ft/sec

8. Fire duration (hours)
   Include the total burn time not just the time fire crews are on the site.

   Default is 6 hours

9. Meteorology source (SASEM, PRESCRIBED)
   Determine whether you have known wind speed, wind direction and dispersion day ranges or if these have yet to be prescribed.
   If the prescription is available enter PRESCRIBED, if not enter SASEM.
   If SASEM is entered, then ranges for the meteorology will be set by the program and a default mixing height used.

   Default is SASEM

10 Wind speed (lowest, highest, mi/hr)
   Give the lower and upper bounds of the wind speed range prescribed for the fire in mi/hr.

   Default lower is 2.0 mi/hr, upper is 10.0 mi/hr
   Remember to type <RETURN> twice if the default is wanted for lower and upper wind speeds.

11. Wind direction range (clockwise, 3 letter abbreviation)
    Give the wind directions, end of range clockwise from beginning, as 1 to 3 letter abbreviations, from the fire prescription.
    (N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, NNW)

    Default is N to NNW
    Remember to type <RETURN> twice if the default is wanted for begin and end wind directions.

12. Dispersion day range (better to worse, Excellent, Good, Fair, Poor)
    Give the dispersion day category(s) as reported by the weather service or for the time of year.

    Default is Good to Poor
    Remember to type <RETURN> twice if the default is wanted for best and worst dispersion days.

13. Mixing Height (m)
    Give the average mixing height during the burn period
    in meters if it is known, otherwise, the default will be used

    Default is 1500 m.

14. Sensitive Receptor Name
    Decide if sensitive receptors are within 50 km of the site.
    These are areas where reduced visibility would be important,
    such as roads, towns and wilderness areas.
    You are allowed up to 10 such sites.
    You must provide a descriptive name for each site.

    Default is no sensitive receptors
    If receptors are used, default name is REC NN
    where NN is the receptor number.

15. Receptor/fire distance (miles)
    Give the distance the fire is from the sensitive site in miles.

    Default is 0.62 mi (1 km) the distance to the 'plant' boundary.

16. Receptor to fire direction
    Give the direction to the fire site when viewed
    from the sensitive receptor area.
    (N = the fire is north of the receptor,
    or NNE, NE, ENE, E, ESE, SE, SSE, S,
    SSW, SW, WSW, W, WNW, NW, NNW)

    Default is fire is North of receptor

    For help while running the model
    type ? in answer to any question.

Disp Day	Wind Speed (MPH)	Maximum Concentration (Microg/m-cube)	Distance to Maximum Concentration (Mi)	Exceedences of Standards Primary* Distance From (Mi)	To (Mi)	Secondary* Downwind From (Mi)	To (Mi)	Plume Rise (m)
EXC	2.0	93.0	2.23	NO VIOLATION		NO VIOLATION		449.
EXC	3.0	93.0	1.55	NO VIOLATION		NO VIOLATION		300.
EXC	4.0	93.0	1.19	NO VIOLATION		NO VIOLATION		225.
EXC	5.0	98.9	.62	NO VIOLATION		NO VIOLATION		180.
EXC	6.0	100.1	.62	NO VIOLATION		NO VIOLATION		150.
EXC	7.0	98.1	.62	NO VIOLATION		NO VIOLATION		128.
EXC	8.0	94.3	.62	NO VIOLATION		NO VIOLATION		112.
EXC	9.0	89.7	.62	NO VIOLATION		NO VIOLATION		100.
EXC	10.0	84.9	.62	NO VIOLATION		NO VIOLATION		90.
GOOD	5.0	93.3	1.99	NO VIOLATION		NO VIOLATION		180.
GOOD	6.0	93.4	1.63	NO VIOLATION		NO VIOLATION		150.
GOOD	7.0	93.5	1.37	NO VIOLATION		NO VIOLATION		128.
GOOD	8.0	96.1	.62	NO VIOLATION		NO VIOLATION		112.
GOOD	9.0	99.0	.62	NO VIOLATION		NO VIOLATION		100.
GOOD	10.0	100.2	.62	NO VIOLATION		NO VIOLATION		90.
FAIR	7.0	93.0	5.83	NO VIOLATION		NO VIOLATION		128.
FAIR	8.0	93.0	4.60	NO VIOLATION		NO VIOLATION		112.
FAIR	9.0	93.0	3.74	NO VIOLATION		NO VIOLATION		100.
FAIR	10.0	93.0	3.10	NO VIOLATION		NO VIOLATION		90.
POOR	2.0	460.6	4.98	1.06	23.62	.69	23.62	98.
POOR	3.0	268.3	6.60	4.11	10.33	1.32	24.00	112.
POOR	4.0	182.8	8.05	NO VIOLATION		2.71	23.59	123.
POOR	5.0	135.8	9.40	NO VIOLATION		NO VIOLATION		133.
POOR	6.0	106.5	10.67	NO VIOLATION		NO VIOLATION		141.
POOR	7.0	86.7	11.87	NO VIOLATION		NO VIOLATION		148.
POOR	8.0	72.5	13.03	NO VIOLATION		NO VIOLATION		155.
POOR	9.0	62.0	14.13	NO VIOLATION		NO VIOLATION		161.
POOR	10.0	53.9	15.21	NO VIOLATION		NO VIOLATION		167.

** THE PRIMARY PARTICULATE STANDARD IS 260. MICROGRAMS PER CUBIC METER*
THE SECONDARY PARTICULATE STANDARD IS 150. MICROGRAMS PER CUBIC METER

Appendix B

Sample of SASEM Results Printout

Your input values from SASEM are:

1. Identifying name for the fire/site	= FIRE
2. Date of the burn	= DATE
3. Burn type of the fire	= BROADCAST
4. Fuel type of the fire	= SAGE
5. Size of the fire	= 150 acres
6. Fuel loading of the fire site	= 5500 lb/acre
7. Fire line intensity	= 195 Btu/ft/sec
8. Burn duration	= 5 hours
9. Meteorology type	= SASEM

Sensitive Receptor Information

Receptor Number	Receptor Name	Receptor Distance	Receptor Direction
1	ONE	10.0	SSW
2	TWO	20.0	SSE
3	THREE	30.0	NE

The SASEM calculated emission statistics are:

Pollutant of interest	= TSP (Total suspended particulate)
Emission factor	= 16.86404 g/kg
Emission rate	= .3149951 g/s/m
Total particulates emitted	= 4.869482 Tons
Proportion of fuel consumed	= .7
Heat content of fuel specified	= 6300. Btu/lb
Residence time of fire front	= 480. s
Fire line rate of spread	= 4.328468E-02 m/s
Approximate fire line length	= 779.1243 m
Depth of the fire line	= 20.77664 m
Number of effective plumes in fire	= 37.5
Heat release rate for a plume	= 1358276. cal/s
Persistence factor for concentration	= .2083333
Proportion of smoke which rises	= .6

Receptor Number	Name	Distance (Mi)	Direction	Disp Day	Wind Speed (MPH)	Range of Wind Direction	P&V* Visual Range (Mi)	Kosh** Visual Range (Mi)
1	ONE	10.00	SSW	EXC	2.0	N - NNW	9.2	4.1
1	ONE	10.00	SSW	EXC	3.0	N - NNW	13.5	6.1
1	ONE	10.00	SSW	EXC	4.0	N - NNW	17.7	8.0
1	ONE	10.00	SSW	EXC	5.0	N - NNW	21.7	10.0
1	ONE	10.00	SSW	EXC	6.0	N - NNW	25.6	11.8
1	ONE	10.00	SSW	EXC	7.0	N - NNW	29.3	13.7
1	ONE	10.00	SSW	EXC	8.0	N - NNW	32.9	15.5
1	ONE	10.00	SSW	EXC	9.0	N - NNW	36.4	17.3
1	ONE	10.00	SSW	EXC	10.0	N - NNW	39.8	19.1
1	ONE	10.00	SSW	GOOD	5.0	N - NNW	21.7	3.4
1	ONE	10.00	SSW	GOOD	6.0	N - NNW	25.6	4.1
1	ONE	10.00	SSW	GOOD	7.0	N - NNW	29.3	4.7
1	ONE	10.00	SSW	GOOD	8.0	N - NNW	32.9	5.3
1	ONE	10.00	SSW	GOOD	9.0	N - NNW	36.4	6.0
1	ONE	10.00	SSW	GOOD	10.0	N - NNW	39.8	6.6
1	ONE	10.00	SSW	FAIR	7.0	N - NNW	29.3	1.3
1	ONE	10.00	SSW	FAIR	8.0	N - NNW	32.9	1.4
1	ONE	10.00	SSW	FAIR	9.0	N - NNW	36.4	1.5
1	ONE	10.00	SSW	FAIR	10.0	N - NNW	39.8	1.6
1	ONE	10.00	SSW	POOR	2.0	N - NNW	9.2	.2
1	ONE	10.00	SSW	POOR	3.0	N - NNW	13.5	.4
1	ONE	10.00	SSW	POOR	4.0	N - NNW	17.7	.6
1	ONE	10.00	SSW	POOR	5.0	N - NNW	21.7	.7
1	ONE	10.00	SSW	POOR	6.0	N - NNW	25.6	.9
1	ONE	10.00	SSW	POOR	7.0	N - NNW	29.3	1.2
1	ONE	10.00	SSW	POOR	8.0	N - NNW	32.9	1.4
1	ONE	10.00	SSW	POOR	9.0	N - NNW	36.4	1.6
1	ONE	10.00	SSW	POOR	10.0	N - NNW	39.8	1.9
2	TWO	20.00	SSE	EXC	2.0	N - NNW	16.2	8.7
2	TWO	20.00	SSE	EXC	3.0	N - NNW	23.5	12.8
2	TWO	20.00	SSE	EXC	4.0	N - NNW	30.3	16.7
2	TWO	20.00	SSE	EXC	5.0	N - NNW	36.8	20.5
2	TWO	20.00	SSE	EXC	6.0	N - NNW	42.8	24.2
2	TWO	20.00	SSE	EXC	7.0	N - NNW	48.5	27.8
2	TWO	20.00	SSE	EXC	8.0	N - NNW	53.9	31.3
2	TWO	20.00	SSE	EXC	9.0	N - NNW	59.0	34.6
2	TWO	20.00	SSE	EXC	10.0	N - NNW	63.9	37.9
2	TWO	20.00	SSE	GOOD	5.0	N - NNW	36.8	6.2
2	TWO	20.00	SSE	GOOD	6.0	N - NNW	42.8	7.4
2	TWO	20.00	SSE	GOOD	7.0	N - NNW	48.5	8.6
2	TWO	20.00	SSE	GOOD	8.0	N - NNW	53.9	9.8
2	TWO	20.00	SSE	GOOD	9.0	N - NNW	59.0	11.0
2	TWO	20.00	SSE	GOOD	10.0	N - NNW	63.9	12.1
2	TWO	20.00	SSE	FAIR	7.0	N - NNW	48.5	1.7
2	TWO	20.00	SSE	FAIR	8.0	N - NNW	53.9	1.9
2	TWO	20.00	SSE	FAIR	9.0	N - NNW	59.0	2.1
2	TWO	20.00	SSE	FAIR	10.0	N - NNW	63.9	2.3
2	TWO	20.00	SSE	POOR	2.0	N - NNW	16.2	.3
2	TWO	20.00	SSE	POOR	3.0	N - NNW	23.5	.4
2	TWO	20.00	SSE	POOR	4.0	N - NNW	30.3	.6
2	TWO	20.00	SSE	POOR	5.0	N - NNW	36.8	.8
2	TWO	20.00	SSE	POOR	6.0	N - NNW	42.8	1.0
2	TWO	20.00	SSE	POOR	7.0	N - NNW	48.5	1.2
2	TWO	20.00	SSE	POOR	8.0	N - NNW	53.9	1.4
2	TWO	20.00	SSE	POOR	9.0	N - NNW	59.0	1.7
2	TWO	20.00	SSE	POOR	10.0	N - NNW	63.9	1.9

3	THREE	30.00	NE	EXC	2.0	N	- NNW	22.8	>99.9
3	THREE	30.00	NE	EXC	3.0	N	- NNW	32.6	>99.9
3	THREE	30.00	NE	EXC	4.0	N	- NNW	41.7	>99.9
3	THREE	30.00	NE	EXC	5.0	N	- NNW	49.9	>99.9
3	THREE	30.00	NE	EXC	6.0	N	- NNW	57.6	>99.9
3	THREE	30.00	NE	EXC	7.0	N	- NNW	64.6	>99.9
3	THREE	30.00	NE	EXC	8.0	N	- NNW	71.1	>99.9
3	THREE	30.00	NE	EXC	9.0	N	- NNW	77.2	>99.9
3	THREE	30.00	NE	EXC	10.0	N	- NNW	82.8	>99.9
3	THREE	30.00	NE	GOOD	5.0	N	- NNW	49.9	73.2
3	THREE	30.00	NE	GOOD	6.0	N	- NNW	57.6	82.9
3	THREE	30.00	NE	GOOD	7.0	N	- NNW	64.6	91.4
3	THREE	30.00	NE	GOOD	8.0	N	- NNW	71.1	99.1
3	THREE	30.00	NE	GOOD	9.0	N	- NNW	77.2	>99.9
3	THREE	30.00	NE	GOOD	10.0	N	- NNW	82.8	>99.9
3	THREE	30.00	NE	FAIR	7.0	N	- NNW	64.6	14.9
3	THREE	30.00	NE	FAIR	8.0	N	- NNW	71.1	16.7
3	THREE	30.00	NE	FAIR	9.0	N	- NNW	77.2	18.5
3	THREE	30.00	NE	FAIR	10.0	N	- NNW	82.8	20.2
3	THREE	30.00	NE	POOR	2.0	N	- NNW	22.8	1.8
3	THREE	30.00	NE	POOR	3.0	N	- NNW	32.6	2.8
3	THREE	30.00	NE	POOR	4.0	N	- NNW	41.7	3.8
3	THREE	30.00	NE	POOR	5.0	N	- NNW	49.9	4.9
3	THREE	30.00	NE	POOR	6.0	N	- NNW	57.6	6.0
3	THREE	30.00	NE	POOR	7.0	N	- NNW	64.6	7.2
3	THREE	30.00	NE	POOR	8.0	N	- NNW	71.1	8.4
3	THREE	30.00	NE	POOR	9.0	N	- NNW	77.2	9.6
3	THREE	30.00	NE	POOR	10.0	N	- NNW	82.8	10.8

** Packham, D. R. and R. G. Vines, 1978, JAPCA 28:790-795.*
***Koshmieder, 1924, Beitr. Phys. Freien Atm., 12:33-54.*
and EPA, 1979, EPA-450/5-79-008.

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16. Abstract (Limit: 200 words)

This Technical Note presents a simple, easy-to-use, computer model of smoke dispersion from controlled burns. This paper contains background on why such a computer program has been developed by the Bureau of Land Management (BLM), the theoretical basis for the model, a guide on how to run the model and suggestions for its use in practical prescribed burning applications.

The Simple Approach Smoke Estimation Model was designed to provide a tool for the analysis of smoke dispersion from prescribed burns. In particular, it was intended to serve as a screening level model which provides a conservative estimate of the possibility that a given burn will cause and exceedence of air quality standards or be a public nuisance due to visibility impairment of public highways or residential areas. By comparison with currently available dispersion models which include line sources, SASEM appears to fulfill this purpose. Furthermore, because of the extremely simple data requirements, all of which are already being collected for purposes or making fire accessible.

17. Document Analysis a. Descriptions

Smoke	dispersion	fires
air pollution	dispersion	hazards
air fquality	pollution monitoring	plumes
particles	computer programs	visibility
visibility	models	

b. Identifiers/Open-Ended Terms

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controlled burns	

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